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Low Field Nuclear Magnetic Resonance (NMR) using SQUIDs

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Using a high resolution SQUID system in a magnetically highly shielded room, we measured the precession of 1H nuclei of liquid benzene, distilled water, and chloroform in magnetic fields around a microTesla. We found that the NMR lines of these liquids are in the range of a few hundred milliHertz and increase linearly with the detection field over a Larmor frequency range of two orders of magnitude. The slope is attributed to the inhomogeneity of the detection field and enables the extrapolation of the natural line width to zero magnetic field. For this limit, where any molecular motion is fast with respect to the Larmor frequency, the natural resonance line widths of benzene, chloroform and distilled water were determined to be 120 mHz, 150 mHz, and 170 mHz, respectively. In low magnetic fields, chemical shift and homonuclear coupling become negligible. All that remains as a source of a spectral structure is pure J-coupling between nuclei of different gyromagnetic ratio. We studied pure J-coupling between methylene protons and fluorine nuclei of trifluorethanol and between methyl protons and phosphorus in trimethylphosphate at detection fields from 0.5 microTesla to 4 microTesla. This corresponds to a variation of d=J(H,F)/(f(H)-f(F)) from 8 to 1 and of d=J(H,P)/(f(H)-f(P)) from 0.8 to 0.08, respectively. At very low fields, i.e. at d=8, the spectra of trifluorethanol exhibited only one single resonance line with an irregular structure. With increasing field, more and more individual lines were revealed. For trimethylphosphate, d=0.08 represents the transition to the weak coupling regime. In addition, we employed a 304 SQUID vector magnetometer system for the recording of the magnetic field generated by water protons in two adjacent sample tubes precessing about a magnetic field of a microTesla. From the spatially resolved data, positions and moments of the samples were calculated, yielding a reconstructed moving image of the two precessing magnetic dipoles.